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MELTING CHARACTERISTICS OF COAL SLAGS

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MELTING CHARACTERISTICS OF COAL SLAGS

by

G. Lemieux*

ABSTRACT

During the viscosity measurements of the coal slag samples obtained from the Canadian Combustion Research Laboratory (CCRL), it was observed that at high temperature and near the softening point of the slag, the slag volume tended to expand. This expansion creates a problem in the viscosity measurements due to overflow and loss of material. The cause of the expansion of the slags at high temperature was examined using a Leitz heating microscope. The results showed that the as-received slag samples contained minor amounts of unoxidized carbon. Near the softening point, the residual carbon is oxidized and, as a result, both CO and CO_2 are released causing the melt to expand. In order to suppress this expansion, the slag samples were calcined at 800°C in air. During the calcining the carbon residue was fully oxidized and hence no expansion of slag should occur during viscosity measurements.

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CARACTÉRISTIQUES DE FONTE DES LAITIERS DE CHARBON

par

G. Lemieux*

RÉSUMÉ

On a constaté, en mesurant la viscosité des échantillons de laitier de charbon obtenus du Laboratoire canadien de recherche sur la combustion (LCRC), qu'à forte température et près du point d'émollition le volume du laitier tend à s'accroître. Il est alors difficile d'en mesurer la viscosité, parce que le laitier déborde et qu'on en perd une partie. La cause de cette dilatation a été étudiée au moyen d'un microscope chauffant Leitz. L'analyse a révélé que les échantillons, à leur réception, renferment de faibles quantités de carbone inoxydé qui s'oxyde lorsque le laitier approche du point d'émollition, ce qui provoque la libération de CO et de CO_2 et, partant, la dilatation du laitier fondu. Pour prévenir cette réaction, nous avons calciné les échantillons de laitier à 800 °C dans l'air. La calcination permet d'oxyder tout le carbone résiduel et devrait empêcher toute dilatation pendant la prise des mesures.

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INTRODUCTION

During the past two years, the Mineral Processing Laboratory of CANMET has been involved in viscosity measurements of the coal slags formed by combustion of western Canadian coals. The primary objective of this study is to provide direct support to determine the cause of slagging in a pilot-scale coal fired boiler. It was observed that during the melting of the slag sample, the melt volume increased by about 1.5 to 2 times the original volume, resulting in overflow of material from the molybdenum crucible. The resulting variation in melt volume is a problem that interferes with viscosity measurements. In order to examine the cause of the volume expansion, the melting characteristics of the slags were determined using a Leitz heating microscope.

EXPERIMENTAL

MATERIALS

The boiler slags were produced by burning western Canadian coals in a pilot-scale boiler at the Canadian Combustion Research Laboratory (CCRL) of CANMET during 1983. Chemical analyses of these samples are not yet available. A total of nine samples were received on August 4, 1983. The sample number and the physical characteristics of the slags are given in Table 1.

MELTING CHARACTERISTICS OF THE SLAGS

Traditionally the flow characteristics of the slags were determined using the ASTM ash-fusion test, in which the shape-temperature dependence of a molten ash cone is observed visually (2). This test defines four characteristic ash-fusion temperatures (AFT's). In this study, the flow characteristics of the slags were examined using a Leitz heating microscope, type II A-P. In this technique, a series of photomicrographs were taken during the heating of a small specimen (2x2x2 mm) to a maximum temperature of 1600°C in air. The flow characteristics of the as-received slags were determined and the temperature of the slag expansion was recorded photographically.

Table 1. List of the slag samples and their physical appearance

Sample Number	Physical appearance
289-83	pulverized slag
A078-83	pulverized slag
A101-83	pulverized slag
A132-83	pulverized slag
A169-83	pulverized slag
A240-83	vitreous chunky slag sample containing pores
A523-83	vitreous chunky slag sample containing pores
A577-83	vitreous chunky slag sample containing pores
A613-83	vitreous chunky slag sample containing pores

RESULTS AND DISCUSSION

Megascopically, the unpulverized slags are vitreous and black to greyish. They also contain mega and micropores. These pores appear to form by the action of gas escaping during melting.

After calcination, the colour of the pulverized slags generally varied from light brown to red. This indicates that by heating the pulverized slags in air, a change occurred in the oxidation state of the iron components, apparently from the ferrous to the ferric form.

The thermal behaviour of the slags, both as-received and after calcining at 800°C, is given in Table 2. It can be seen that expansion is a common phenomenon for the as-received samples, which occurred at a temperature about or slightly higher than the hemispherical temperature. Typical examples of the expansion characteristics of the as-received and calcined samples are shown in Figure 1 as recorded photographically during heating. A substantial increase in volume is noted for the as-received sample when compared with the calcined sample.

It appears that the likely cause of the expansion is the oxidation of the fine carbon particles present in the samples. Between initial softening and the hemispherical temperature, CO and CO_2 gases are formed, which causes foaming and expansion of the melt. The degree of expansion appears to depend on the amount of carbon present, as well as the rate at which these gases are liberated from the sample. In the calcined samples, the carbon particles were fully or partially pre-oxidized, little or no CO and CO_2 were formed and thus the expansion phenomenon was not observed at above the hemispherical temperature.

In order to suppress the expansion of the melt, it is recommended that the as-received slags be calcined at a temperature of 800°C in a steady flow of air for a period of at least 1 h. It is highly desirable to grind the sample as fine as possible to increase the surface area of the carbon particles and expose them fully to the oxidizing environment.

Table 2. Thermal behaviour of as-received and calcined slag samples

Sample number	As-received				Calcined			
	S	H	E	F	S	H	E	F
289-83	1350	1390	1400	1430	1350	1400	----	1450
A078-83	1275	1300	1300	1320	1250	1300	----	1320
A101-83	1260	1300	1330	1350	1260	1300	----	1340
A132-83	1300	1320	----	1350	1300	1320	----	1360
A169-83	1260	1310	1330	1370	1260	1300	----	1430
A240-83	1320	1400	1400	1430	1330	1400	----	1420
A523-83	1350	1420	1450	1470	1360	1420	----	1470
A577-83	1330	1370	----	1400	1340	1380	----	1420

S=softening temperature, °C

H=hemispherical temperature, °C

E=expansion temperature, °C

F=fluid temperature, °C

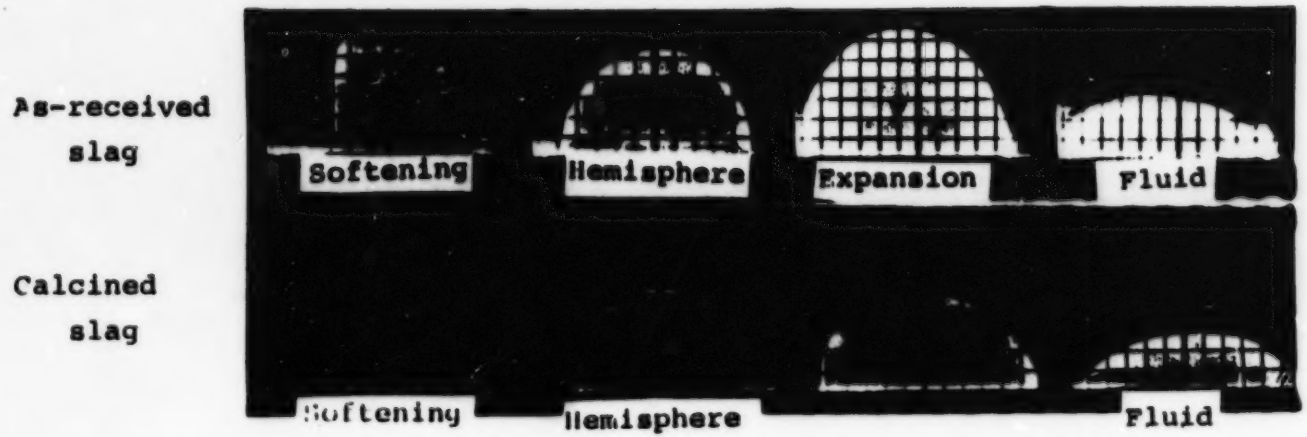

Fig. 1. Thermal behaviour of as-received (upper) and calcined (lower) slags.

CONCLUSION

During viscosity measurements of coal slags provided by the Canadian Combustion Research Laboratory, it was observed that during the melting the volume of the melt increased and the melt overflowed the crucible. The loss of material due to this expansion hindered the viscosity measurements. The melting behaviour of the slags was investigated using the heating microscope. The results showed that the expansion occurred at about or slightly above the hemispherical temperature. The expansion phenomenon is attributed to foaming by CO and CO_2 gases formed within the sample by oxidation of residual carbon. Pre-calcining the ground slags at 800°C in a steady flow of air for at least one hour prevents foaming and loss of melt, thus enabling accurate viscosity measurements. This practice has been adopted for all viscosity measurements on these and similar materials.

REFERENCES

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